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EXECUTIVE SUMMARY

INSPECTION OF ELASTOMERIC CONTRACTION JOINTS IN PRESSURE RELIEF DUCT, PICKERING NGS 'A'

D.C. Cordingley

Six rectangular contraction/expansion joints in the pressure relief duct (PRD) and four similar circular joints to the reactor buildings of Units 1 to 4 were examined from inside the duct for signs of deterioration and damage. The durometer hardness of the seals were about 10 A units above the nominal 55±5 A units specified. This indicates that these seals have only hardened and aged a small amount since installed in 1970/1971. At the field splice sections, however, the seals had hardened to the high eighties and low nineties level of hardness on the A scale. Residual stains characteristic of blooming also occurred at the field splice sections. A feeler gauge 0.102 mm (0.004 inch) thick penetrated the flange rubber junction at a number of locations where there was no sign of air leakage trails. On vertical and ceiling runs, some of the bolts at feeler penetrated locations were mildly rusted and showed white trails from water leakage. In the floor of the joints the bolts and the flanges were severely rusted at many locations. A considerable number of sites may exist which leak, or have features that facilitate leakage. With the exception of the seal in the east end of the duct, all the remaining seals were black. The black seals were assumed to be neoprene, the red seals silicone rubber. The polysulfide caulking at the outside edge of the silicone seal does not extend to the clamping flange, as does the caulking on the neoprene seals, and hence does not provide a supplementary barrier to leakage. The splice on the silicone rubber seal was located on the top of the duct and was in a good condition. Mechanical damage was limited to a single slit about 10 cm long which penetrated to the fabric on the circular seal at the junction of the PRD with Unit 4 reactor building. With this exception and the hardening of the field splices on the neoprene seals, the contraction joint seals and sealing system are deemed to be in a excellent condition after sixteen years of service.

job	file	date	report no.
32-050-058	835.6211	October 15, 1987	87-150-K

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To: Mr. E. Dewar
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INSPECTION OF ELASTOMERIC CONTRACTION JOINTS IN PRESSURE RELIEF DUCT, PICKERING NGS 'A'

D.C. Cordingley

Six rectangular contraction/expansion joints in the pressure relief duct (PRD) and four similar circular joints to the reactor buildings of Units 1 to 4 were examined. The durometer hardness of the neoprene seals were about 10 A units above 55±5 A units specified, whereas the field spliced sections were 30 A to 40 A units above the level specified. Although the seals have only hardened and aged a small amount since installed in 1970/71, the field splices have hardened and bloomed. A feeler gauge 0.102 mm thick penetrated the flange rubber junction at several locations. Corrosion and residues from water leakage were also present at a number of the bolt holes. Mechanical damage was limited to a single slit about 10 cm long which penetrated to the fabric. With the above exceptions the seals and sealing system are deemed to be in an excellent condition after sixteen years of service.

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32-050-058	835.6211	October 15, 1987	87-150-K

Containment across the contraction joints on the A section of the pressure relief duct (PRD) is provided by fabric reinforced elastomeric coated seals which bridge the joints and are attached by clamping flanges as illustrated in Figure 1, of Appendix 1. The seals were manufactured by Dunlop Canada Ltd and by Uniroyal Ltd and were installed in 1970 and 1971 respectively/1/. These seals are part of the vacuum containment system and for this reason were included in the inspection program. During January 1987, six rectangular contraction/expansion joints in the PRD and four similar circular joints to the reactor buildings of Units 1 to 4 were examined from inside the duct for signs of deterioration and damage. The location of these joints in the PRD are shown in Figure 2 of Appendix 1. This report details the measurements, observations and findings of this inspection.

Measurements and Observations
Used for Inspection of Seal

The exposed surface of the fabric reinforced elastomeric seal which spans the joint was visually examined for signs of deterioration and/or damage. This required a complete traverse of the 90 ft length of seal at each joint. The visual examination was aided by a 2 X magnifying glass. Concurrent with these activities the durometer hardness of each seal was periodically and randomly measured as the seal was traversed. Similar measurements were made on a number of splices. The instantaneous durometer hardness measurements were made with a Rex A instrument by the method described in ASTM D 2240-86, "Standard Test Method For Rubber Property - Durometer Hardness". The tightness of the clamping system holding the membrane seal in place was probed with a 0.102 mm thick feeler gauge between the clamping flange and the seal at twenty randomly selected spans across the six inch bolt centers on the contraction joints and the twelve inch bolt centers on the hinge joints. Photographs were taken of damage or deterioration to the membrane seals and their splices, typical examples of feeler gauge penetrations, leakage trails and stains, corrosion sites on the clamping flanges and bolts, and construction and other debris in the floor trough formed by the seal. The following conditions were noted:

1. Colour of Seals

   With one exception, all the seals are black in colour, however, seal No. 0 is coloured red.

2. Durometer Hardness of Membrane Seals

   The data for the durometer hardness are summarized and presented in Appendix 2. The mean durometer hardness of the black coloured seals and their field splices were 63.8 A units and 87.3 A units respectively. The hardness of a black splice made at the manufacturer's plant was 66.2 A

units. The hardness of the red coloured seal was the same as the black coloured seals. The range in hardness was between 61.4 and 65.9 for the seals and between 84.4 and 90.0 for the black coloured splices. The variability in durometer hardness within these groups is attributed to experimental error in the measurements.

3. Feeler Gauge Penetration

Sites on the contraction joint where the feeler gauge penetrated between the clamping flange and the seal are identified in Table 1 of Appendix 1. Photographs 1, 2, 3 and 4 of this appendix illustrate the penetration of the feeler gauge. Although only about one-third of the spans between adjacent bolts were examined, a total of eighteen sites were located which could be penetrated by the feeler gauge. An additional penetration site was found on a black coloured seal which showed a tell-tale fan-shaped deposition of air-borne dust radiating from a bolt hole and the edge of the flange (photographs 3 and 4).

4. Splice Sections

The field splices installed during construction are located in the floor section under the floor panel. The splices in the black coloured seals are readily identified by a white bloom on the surface of the seal which could be wiped off by hand. Photographs showing this condition are presented in Appendix 3. The splice on the red coloured seal on Joint No. 0 was located at the top of the duct and was without any sign of blooming.

5. Elastomeric Caulk

On all black coloured seals the elastomeric caulk was located as illustrated in Figure 1 of Appendix 1. On the red coloured seal of Joint No. 0 the caulk did not extend to the exposed edge of the seal.

6. Corrosion of Clamping System

A wide range of corrosion was present on the bolts and flanges of the expansion joints. Corrosion was particularly severe in floor section of the joint from water leakage or air line condensate water. Photographs showing the type and degree of corrosion are presented in Appendix 4. On vertical and ceiling runs, some of the bolts at feeler penetrated locations were mildly rusted and showed white trails of deposits from water leakage, Appendix 5.

7. Construction Debris

A variety of construction debris was found in the trough formed by the seal in the floor of the expansion joints. Photographs of the construction debris, and, nails, rocks and wood are also included in Appendix 4 and in the companion report issued by the Civil Research Department on the condition of the concrete structure/2/.

8. Mechanical Damange

Mechanical damage was limited to a single slit about 10 cm long which penetrated to the fabric on the circular seal at the junction of the PRD with Unit 4 reactor building. The slit occurred at the 5 o'clock position, when facing the bulkhead, and ran in the same direction as the seal. The fabric appears to have been damaged. The site and slit is shown in the photographs of Appendix 6.

DISCUSSION

Two types of elastomers are present in the expansion joints examined. The black coloured seals are assumed to be the polychloroprene (neoprene) seals produced by the Dunlop Rubber Co and by Uniroyal Canada Ltd/1/ which were made to the same formulation and to the specification which was used for the vacuum building roof seal/3/. The red coloured seal is assumed to be the glass fabric reinforced silicone elastomer which was used on the Unit 5 and 6 sections of the duct/4/. The characteristics of these seals have been previously described/5,6/.

The durometer hardness of the seals, both neoprene and silicone, were about 10 A units above the nominal 55$\pm$5 A units specified/4/. This indicates that these seals have only hardened and aged a small amount since the neoprene seals were installed in 1970/1971 assuming that the hardness of the seals were within specifications when installed. The silicone seal was probably installed after 1979. The 30 A unit increase in durometer hardness at the neoprene spliced sections which were made in the duct indicates that the rubber in these splices has deteriorated. Residual stains characteristic of blooming also occurred at the field splice sections. Blooming occurs when various components of the elastomer splice have migrated to the surface of the spliced seal. It is not known if the hardening and blooming occured during the preparation of the field hot splice, or if the rubber in the splice was changed by the thermal splicing.

On the basis of the portion of spans between bolt holes which were tested and which could be penetrated by the feeler gauge, it is estimated that at least twenty sites exist in the duct where the seal between adjacent bolts is under very little or no

compression. Although only one site was found where the tell-tale fan-shaped deposition of air-borne dust has occured because of leakage through a bolt hole into the duct at sub-atmospheric pressure, and at a junction of the upper flange and elastomeric caulk, numerous other sites are present at bolt holes which show deposits from the entrance of water leakage. Obviously a considerable number of sites exist which leak, which have leaked or which have features that facilitate leakage. It is not known if these leakage sites are due to defective bolt holes in the seal similar to those reported earlier/12/.

The severe corrosion of the flanges, exposed bolts and nuts in the floor section of the joints is unlikely to affect the long term performance or life of the elastomeric seals. However, should the corrosion cause the bolts to be damaged when the nuts are removed in order to replace or repair a seal, then the likelihood of achieving acceptable levels of compression in the replaced seal will be greatly reduced.

The accumulation of construction debris and what appears to be maintenance garbage in the floor joints is indicative of poor plant housekeeping practices. Obviously sufficient debris in the floor trough could impede the movement of the joint and the rubber seal. Debris at an embrittled splice location is of primary concern as this could contribute to seal failure should the seal be required to sustain a LOCA incident.

The paucity of identifiable leak sites in the leakage prone neoprene seal clamping system is likely due to the application of the polysulphide caulking to cover the exposed edge of the seal and adjacent outside clamping bar as illustrated in Figure 1 of Appendix 1. This was not done for the silicone rubber seal in the Pickering A NGS section of the PRD where the edge of the seal was left exposed to the atmosphere of the duct which results in leaksites. This inference is based on previous experience in installing seals in the Pickering NGS 'B' section of the PRD. When the silicone rubber seals were installed in the Pickering B NGS section of the PRD, that section of the duct was pressurized to 13.8 KPa and the flange and bolts were measured for an acoustical emission of escaping gas. Where a leak occurred an arrow was marked on the wall reported for Unit 5/12/. RTV silicone was then applied to the marked area while the duct was pressurized until acoustrial silence was obtained by movement of the RTV caulk into the leak channel. It is likely that the same frequency of leakage sites would be obtained in Joint No 0 of a pressurized A section, as illustrated in the Photograph from Unit 5 for the joints in the pressurized B section of the duct.

With the exception of the 10 cm long slit in the surface of the seal on Joint No 27, the rubber contraction joint seals appear to be sound. Although the fabric at the base of the slit appears to

have been damaged, this does not infer that this seal will rupture under the pressure pulse of a LOCA incident, but rather that the reliability of this seal is less than for the other seals.

It should be recognized that the above observations of durometer hardness, penetration of feeler gauge and corrosion are not consistent with the conclusions drawn from the "limited examination" undertaken during the May 1980 station outage. The report of the 1980 inspection cautioned that for the data collected by the field crews "the accuracy of these (durometer hardness) measurements is suspect"/7/.

CONCLUSIONS AND RECOMMENDATIONS

In general the contraction joint seals and sealing system are deemed to be in an excellent condition after sixteen years of service. The following maintenance could be undertaken:

1. It is suggested that the floor trough and adjacent cover sections of the seals be cleaned of all construction debris, sand, nails, corrosion products and other debris. Most of the unwanted material could probably be removed by a commercial or household vacuum cleaner, but the moist sand and silt will probably have to be spooned out by hand. A careful hand wash and light scrubbing with a detergent solution will probably return the joints to their initial condition.

2. The severely corroded flanges, bolts and nuts should be inspected and if needed refurbished and the hardware repainted. Considerable care will have to be taken otherwise the rubber seals could be damaged. Ideally the flanges should be removed and the hardware and embedded bolts and seating angle flange cleaned and protected from further corrosion.

3. The bolts adjacent to the leak site with the fan-shaped deposition of outside dust should be retorqued and the deposit removed so that the effectiveness of the retorqued bolts could be determined at a later date.

4. During the next plant shutdown every bolt and span between bolts should be systematically probed for penetration by a feeler gauge. Any evidence of penetration should demand retorquing of adjacent bolts to remove this condition.

Unlike the seals which show no signficant hardening and aging, the spliced sections of the black coloured neoprene seals, which were joined at the station, have hardened considerably. As this inspection is the first reliable examination in sixteen years it is impossible to estimate if this deterioration has stabilized, is continuing or is accelerating. Further monitoring is required.

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12. Cordingley, D.C., "Integrity of Splices and Bolt Hole Penetrations In Pressure Relief Duct Seals Pickering GS," Research Division Report No. 82-111-K, File 835.6211, May 13, 1982.

APPENDIX 1

Notes On Response of Seals To Penetration By Feeler Gauge At Junction of Seal And Clamping Bar (Gauge 0.107 mm thick)

Unless otherwise reported, only about one-third of the spans between adjacent bolts were probed with a 0.102 mm thick feeler gauge, 3 inches long and 0.5 inches wide. This activity is illustrated by photographs 1 and 2. Penetration by a feeler gauge between the seal and the clamping bar merely indicates the absence of a clamping load and a compression of the seal between the bolt holes. Penetration also indicates that the sealing path across the flange has been greatly reduced. These effects may be summarized pictorially by Figure 1 which shows the location of the elastomeric seal in a contraction joing, by Figure 2 which shows the location of the joint in the duct, and by Figure 3/9,10/ which shows the distribution of compression of the seal between the bolt holes at three levels of bolt torque. The consequence of this response and the retention of the sealing force at operating temperatures is shown in Figure 4 for the silicone elastomeric seal in Joint No 0 after accelerated air oven aging/6/. The retention of sealing force for the black coloured polychloroprene seals in the PRD would be much less under normal aging or accelerated air-oven aging, and at operating temperatures below room temperature. Penetration by a feeler gauge indicates that the site is at or near a condition where leakage can occur. Such a leakage is shown in the photographs Nos 3 and 4 where leakage has already commenced at a seal in the PRD.

Photograph No 1 illustrates the ease and depth of penetration which occurs on the hinge joint. The bolts on these joints are located at 12 inch centers. The reason for this ease of penetration is illustrated in Figure 5/11/ for a FPM/FEP laminated membrane seal in an expansion joint at Lakeview TGS. In this example the same type of clamping system and dimensions are used as illustrated in Figures 1 and 3. The loss of mid-span clamping occurs as the bolt span exceeds 10 cm (4 inches). This becomes quite pronounced for a 15 cm (6 inch) span and the loss presumably continues to increase until a 30 cm (12 inch) bolt span is reached. This effect is presented to account for the greator ease of penetration by the feeler gauge between clamping flange and seal in the hinge joints than in the contraction joints.

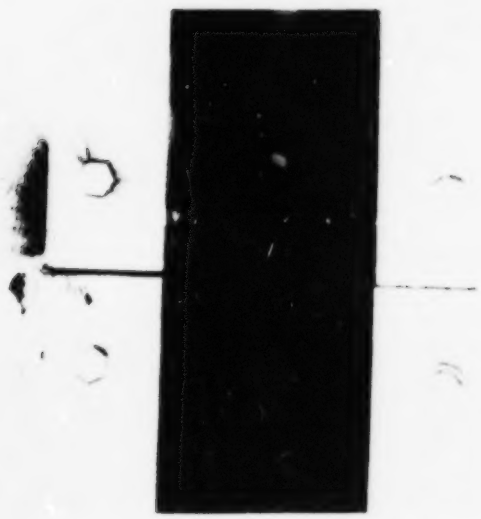
Photograph 1

Photograph 2

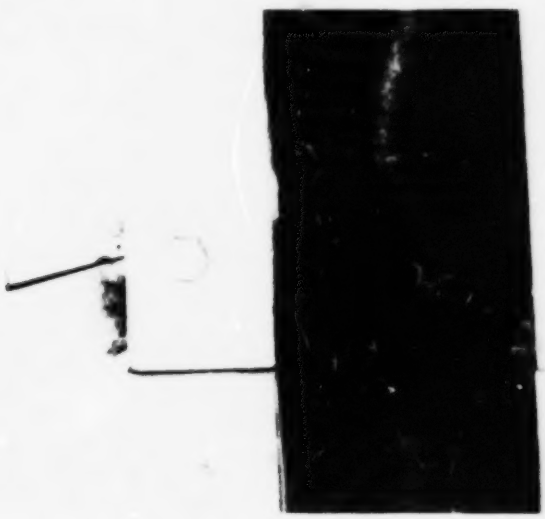
METHOD FOR THE DETERMINATION OF CLAMPING FORCE ON SEAL AT JUNCTION OF SEAL AND FLANGE ACROSS SPAN BETWEEN BOLTS

1. For Hinge Joint, 12 inch bolt centers
2. For Contraction Joint, 6 inch bolt centers

Photograph 3



Photograph 4



LEAKAGE TRAILS FROM DEPOSITION OF OUTSIDE AIR-BORNE DUST INTO PRD

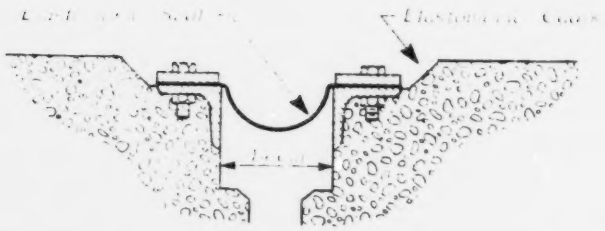


FIGURE 1

LOCATION OF ELASTOMERIC SEAL IN CONTRACTION JOINT
ON PRESSURE RELIEF DUCT - PICKERING NGS

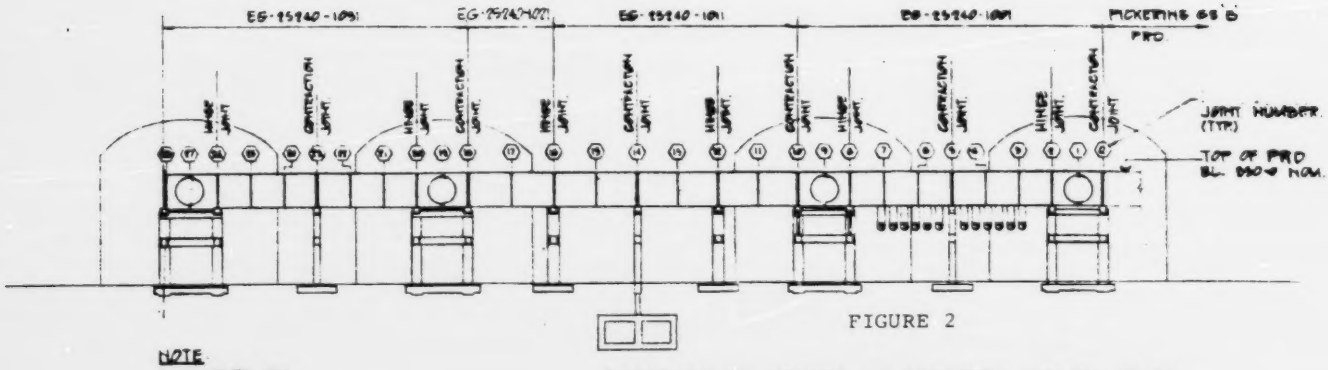


FIGURE 2

NOTE
ALL JOINTS ARE TYP. CONSTRUCTION JOINTS UNLESS NOTED

LOCATION OF JOINTS IN PRESSURE RELIEF DUCT,
PICKERING NGS

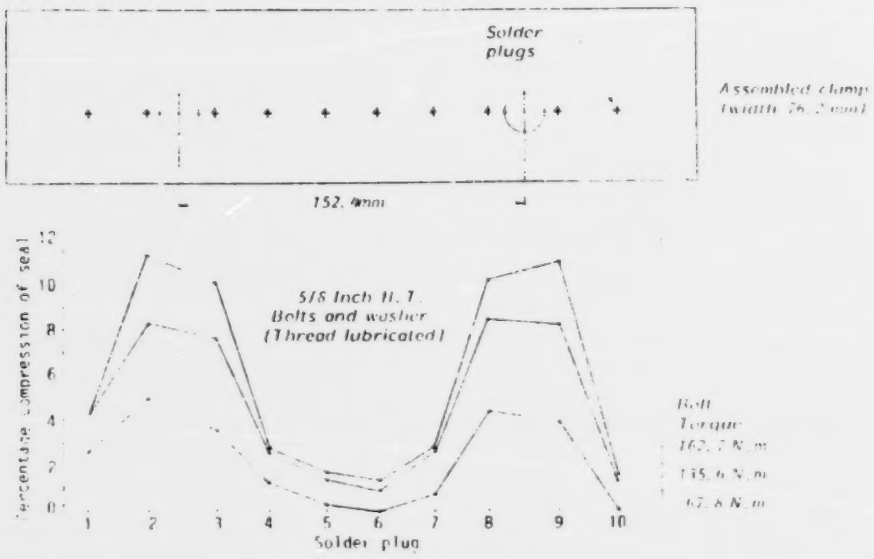


FIGURE 3

EFFECT OF BOLT TORQUE ON COMPRESSION OF SILICONE ELASTOMERIC SEAL WHEN INSTALLED ON A SECTIONAL UNIT OF THE CLAMPING FLANGE ASSEMBLY OF THE CONTRACTION JOINTS IN THE PRESSURE RELIEF DUCT, PICKERING NGS
TEST PERFORMED TO ASTM E-36 ON FULL SCALE FLANGE FOR RECTANGULAR DUCT 51

consequence of this response and the retention of the sealing force at operating temperatures is shown in Figure 4 for the silicone elastomeric seal in Joint No 0 after accelerated air oven aging/6/. The retention of sealing force for the black coloured polychloroprene seals in the PRD would be much less under normal aging or accelerated air-oven aging, and at

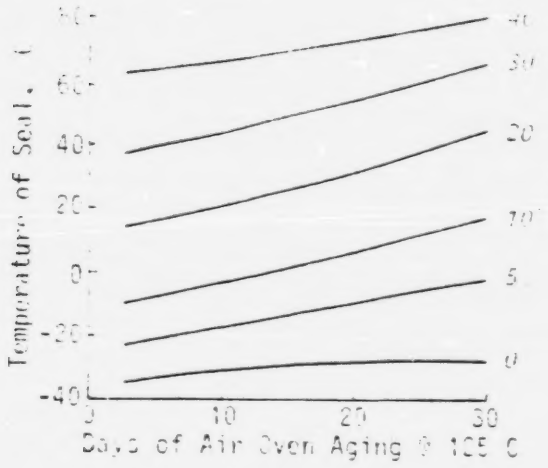


Figure 4

Experimental Response of % Retention of Sealing Force as a Function of Temperature of Seal and Duration of Thermal Exposure at 125°C

operating temperatures below room temperature. Penetration by a feeler gauge indicates that the site is at or near a condition where leakage can occur. Such a leakage is shown in the photographs Nos 3 and 4 where leakage has already commenced at a seal in the PRD.

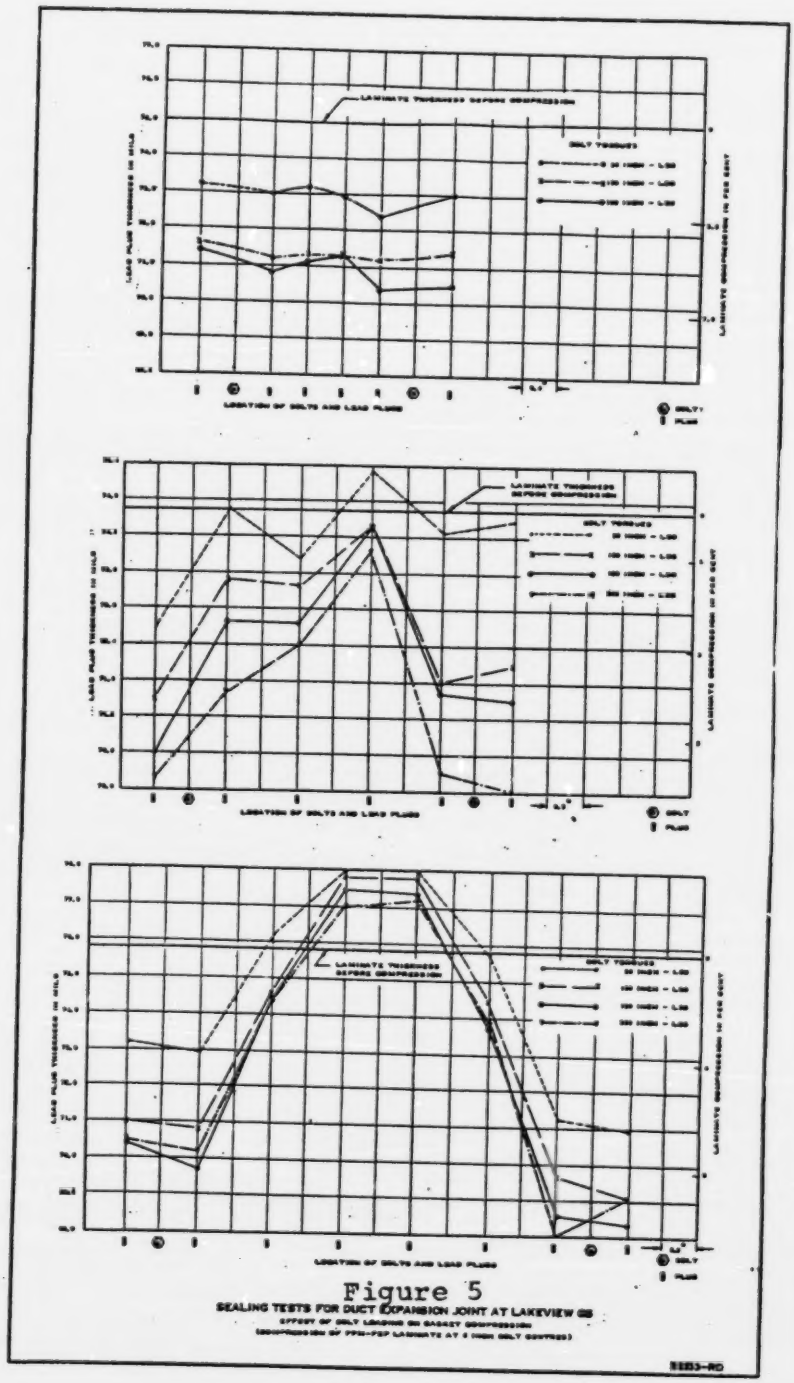


Figure 5

SEALING TESTS FOR DUCT EXPANSION JOINT AT LAKEVIEW GS

TABLE 1

Location of Penetrations by Feeler Gauge (0.102 mm thick) Between Clamping Flanges and Seals on Expansion Joints, Pressure Relief Duct, Pickering A, NGS

Joint Type and Number	Observations* and Identification of Penetration Sites
I CONTRACTION JOINTS	
0	No gaps were found.
1	Gaps found at locations S36a, N53a, N74a, N75a, N76a, N119a and N120A. There seemed to be an irregularity in the clamping fixture at the splice.
5	Gap found at W171a on the north wall. Only limited areas could be examined.
9	Gap found at N17a.
10	Gap found at W107a on top of duct and at W126a on the slant at top of north wall.
14	Gap found at W46a and W51a on the south wall and at W126a on the north wall.
18	Gap found at E126a on upper slanted east flange. Only twenty locations selected at random.
19	No gaps were found.
23	Only twenty locations were selected at random. On the south wall a gap was found between bolts 5 and 6 up on the west clamping flange. On the north side a gap was found between bolts 19 and 20 down on the west clamping flange.
27	One gap was found at the center of the east side, north clamping flange.
II HINGE JOINTS	
26	No systematic search was undertaken.

* Unless otherwise noted only about one-third of bolt spans were examined.

APPENDIX 2

Test Data for Measurements of Durometer Hardness of Contraction/Expansion Joints in Pressure Relief Duct, Pickering NGS

Joint Number	Location in Duct			Durometer Hardness Rex A Instrument, ASTM D2240-86 Number of Measurements N	MEAN $\bar{X}$	Standard Deviation σ_{N-1}
0	North Wall	Top		5	62.0	0.71
		Middle		5	62.8	1.30
		Bottom		5	64.4	2.61
	South Wall	Top		5	62.6	0.89
		Middle		5	63.0	1.00
		Bottom		5	64.4	1.14
		Floor		10	63.2	1.40
			Pooled Data	40	63.2	1.52
1	West Side	Bottom		5	63.4	1.14
	East Side	Bottom		5	63.6	1.82
			Pooled Data	10	63.5	1.43
5	North Wall	Bottom		5	65.6	2.19
	South Wall	Bottom		5	64.6	2.07
			Pooled Data	10	65.1	2.08
9	West Side	Bottom		5	62.4	2.30
	East Side	Bottom		5	63.8	1.92
			Pooled Data	10	63.1	2.13
10	North Wall	Top		5	63.2	1.48
		Middle		5	64.2	2.77
		Bottom		5	66.6	1.34
		Floor		5	67.0	1.58
	South Wall	Bottom		5	61.2	0.83
		Middle		5	63.4	1.52
		2 m from Top		5	65.8	2.17
			Pooled Data	35	64.5	2.54
	Splice	Floor		5	84.4	2.30

APPENDIX 2 Cont'd

Test Data for Measurements of Durometer Hardness of Contraction/Expansion Joints in Pressure Relief Duct, Pickering NGS

Joint Number	Location in Duct		Durometer Hardness Rex A Instrument, ASTM D2240-86 Number of Measurements N	MEAN $\bar{X}$	Standard Deviation σ_{N-1}
14	North Wall	Top	5	67.6	1.14
		Middle	5	63.8	1.64
		Bottom	5	64.4	1.52
	South Wall	Bottom	5	65.8	1.92
		Floor	5	66.2	1.48
		Pooled Data	25	65.6	1.98
	Splice	Floor	5	89.4	3.21
18	North Wall	Top	5	65.6	1.82
		Middle	5	63.6	1.82
		Bottom	6	63.7	2.42
		Floor	5	65.8	1.10
	South Wall	Middle	5	63.2	1.30
		Bottom	6	62.0	3.29
		Pooled Data	32	63.9	2.40
	Splice	Floor	5	85.2	2.86
19	West Side	Bottom	6	62.2	1.60
	East Side	Bottom	6	60.7	2.16
		Pooled Data	12	61.4	1.98
23	North Wall	Top	5	65.0	1.22
		Bottom	5	60.8	1.30
	South Wall	Top	5	64.2	1.10
		Middle	5	66.0	1.22
		Bottom	5	64.8	2.17
		Floor near Splice	5	65.6	1.95
		Pooled Data	30	64.4	2.24
	Splice	North Wall (Plant)	5	66.2	2.39
		Floor (Field)	5	90.0	6.96

APPENDIX 2 Cont'd

Test Data for Measurements of Durometer Hardness of Contraction/Expansion Joints in Pressure Relief Duct, Pickering NGS

Joint Number	Location in Duct	Durometer Hardness Rex A Instrument, ASTM D2240-86 Number of Measurements N	MEAN $\overline{X}$	Standard Deviation σ_{N-1}
27	At 90 degrees	5	62.2	1.64
	At 150 degrees	5	60.8	2.28
	At 210 degrees	5	62.0	1.87
	At 270 degrees	5	61.8	1.48
	Pooled Data	20	61.7	1.78

Summary:

MEAN $\overline{X}$ of all pooled data for seal	224	63.8	-
MEAN $\overline{X}$ of all pooled data for field splice	20	87.3	-
MEAN $\overline{X}$ of all pooled data for plant splice	5	66.2	-

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HINGE Joint No 26	Sides	-	60 to 70
	Center	-	60 to 64

Note: Splice 0 is the red coloured silicone rubber seal, all other seals are black in colour and are presumed to be the original neoprene seals manufactured by Dunlop Rubber Co. and Uniroyal Canada Ltd.

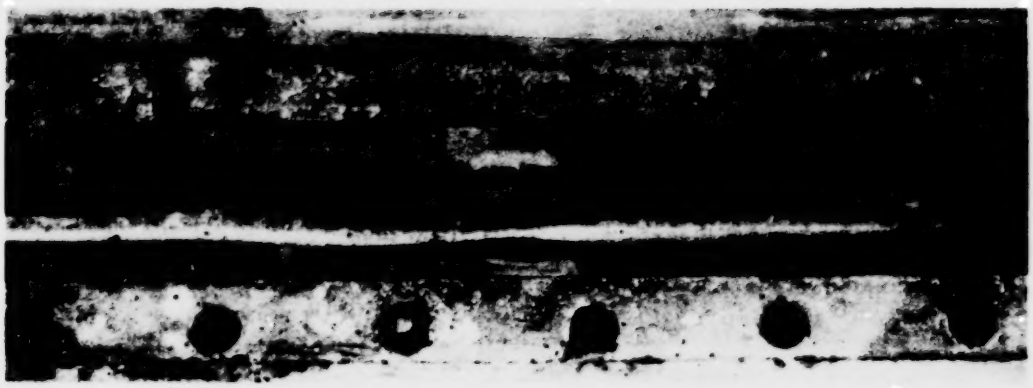
APPENDIX 3

Photographs Showing White Bloom On Surface of Splice Section of Elastomeric Contraction Joints in Pressure Relief Duct Pickering A NGS

Photograph No. 1

Photograph No. 2

Photograph No. 3



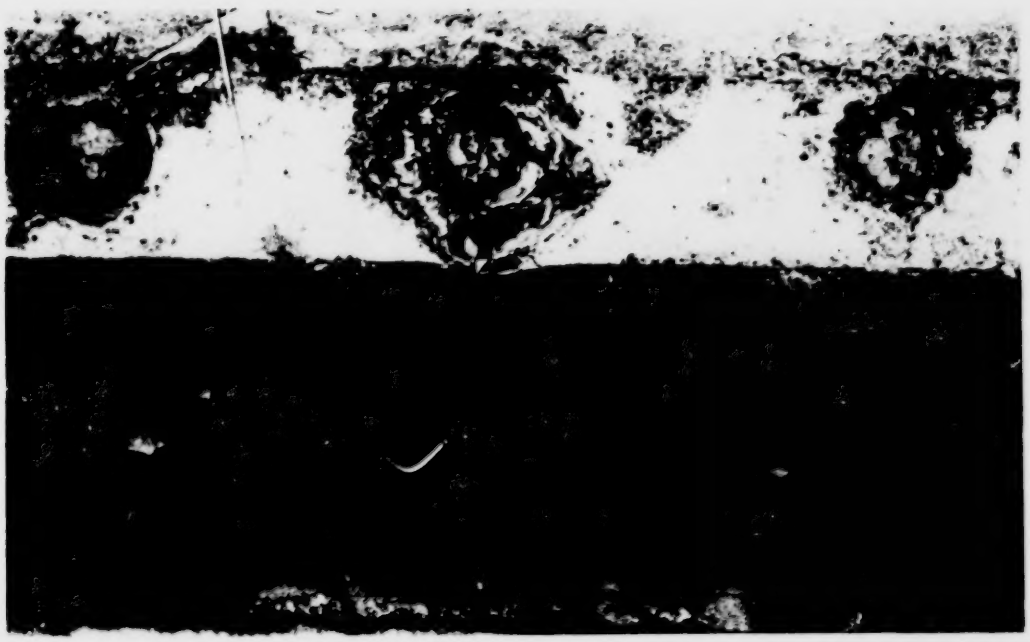
Photograph No. 4

APPENDIX 4

Photographs Showing Debris In Floor Trough
Corrosion To Bolts, Nuts and Flanges Of Clamping
System Holding Elastomeric Contraction Joints
In Pressure Relief Duct, Pickering A NGS

Photograph No. 1

Photograph No. 2



—Photograph No. 3

Photograph No. 4—

—Photograph No. 5

Photograph No. 6

APPENDIX 5

Photographs Showing White Trails Of Deposits From Water Leakage Through Bolt Holes On Contraction Joint Pressure Relief Duct, Pickering A NGS

Photograph No. 1

Photograph No. 2

APPENDIX 6

Photographs Showing Mechanical Imduced Slit In Surface of Elastomric Seal in Joint No 27, Pressure Relief Duct Pickering A NGS

Photograph No. 1

Photograph No. 2

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